Evaluation of Raw and Decomposed Leaves For Soil Improvement in Home Gardens

By David E. Hill

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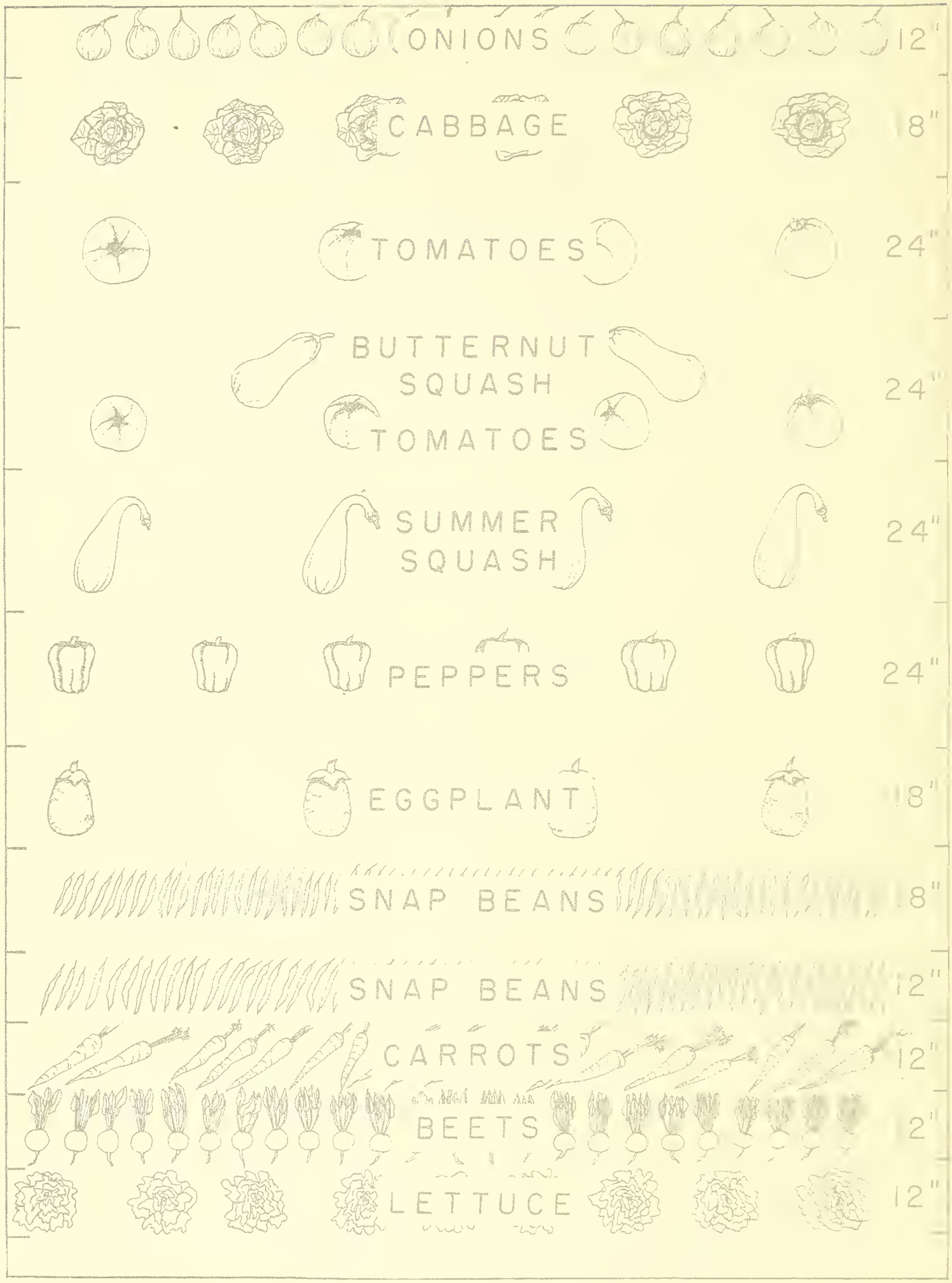

Planting Diagram for the Day-Waverly Gardens. The number of cabbages, tomatoes, peppers, lettuce, and eggplants were as shown, as were the number of hills of yellow and butternut squash (4 plants per hill). Onions, snap beans, and beets were thinned to 3 inch spacing; carrots were thinned to 2-inch spacing.

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Droughty soils are common in Connecticut's valleys and ridges where one acre in three is marginal for crop production because it will not hold enough water for adequate plant growth. Little water is available from very sandy soils because they contain few small pores to hold water against gravitational pull. Such soils drain rapidly, allowing water to seep beyond the reach of plant roots. In soils underlain by bedrock at depths of 12-15 inches, root growth is restricted and plants can only use the limited water held in that shallow zone. Farmers avoid these marginal soils that require large additions of organic matter or expensive irrigation. But droughty soils are often found in backyards where gardens are faithfully tended despite their limitations. The success of the gardener of droughty soil depends on his ability to overcome moisture limitations.

The epitome of droughtiness in soil is found in vacant lots within Connecticut's cities. Here, houses have been razed and their cellar holes filled with a mixture of sand, brick, mortar, and other urban artifacts. Such vacant lots have recently become sites for community gardens. The sponsor of one such garden, the Greater New Haven Arts Council, came to the Experiment Station with the challenge of improving the droughty soil in an inner-city community garden. This request led to experiments in 1976 in improving the moisture-holding capacity of the droughty soil used for the community gardens in New Haven.

Based on the results of this first year of research, the garden was amended with leaf-mold in 1977 and experiments were conducted to determine the effects of the rate and timing of fertilization on yields.

Similar experiments were conducted at Lockwood Farm in Mt. Carmel with various rates of application of leaf-mold on a droughty soil underlain by bedrock at a shallow depth. In 1978 we conducted experiments on our leaf-mold amended soils to improve the germination of vegetable seeds whose mortality rates were higher on the cooler and wetter soil.

Many homeowners, however, do not have a supply of fully composted leaf-mold. Instead, they apply fresh uncomposted leaves or only partially composted leaves to their vegetable gardens to improve moisture holding properties of the soil. In 1979 and 1980 we compared the effects of applying composted, partially composted, and uncomposted leaves on the yields of crops.

Finally, these experiments also allowed estimation of the economic yield that can be expected from a garden supplied with optimal fertilizer and water.

METHODS

Site and Soil

The Day-Waverly Community Gardens are a few blocks from the center of New Haven in a corridor cleared of houses in the mid-1960s in anticipation of reconstruction of Connecticut Route 34. The land, which had been idle for 10 years, had accumulated great quantities of debris and demolition waste. After the New Haven Department of Public Works removed surface debris, the ¾-acre lot was plowed. About 60 families then removed the debris dislodged by the plow. The Experiment Station conducted experiments in a 20×40-foot area of the garden.

The sandy, coarse textured soil had a low moisture holding capacity. Its native fertility was low. The neutral pH (6.9) was due to mortar in the soil. There are almost 40 more frost-free days in urban New Haven than in suburban Mt. Carmel (Havens and McGuire, 1961). Planting dates were about a week earlier at the urban site and the first killing frost was about 10 days later than at Mt. Carmel. Thus, the growing season was about 2.5 weeks longer in the city.

The plots at Lockwood Farm were in a flat field at the broad crest of a low drumloidal ridge. The loamy soil has been mapped as Yalesville fine sandy loam by the Connecticut Cooperative Soil Survey. The most notable characteristic of this soil type is its weakly cemented bedrock at a depth of 20 to 40 inches. However, the bedrock in the vicinity of the plots is only 12-14 inches below the surface. Thus, the soil must be classified as a taxadjunct of the Yalesville series. In 1979, the experiments were moved a short distance to an adjacent field where the depth to rock exceeds 4 feet. This soil is classified as Cheshire fine sandy loam. Its physical characteristics are similar to the Yalesville soil except that it is deeper and has a loamy sand substratum.

The area used for the experimental plots was divided into four 10×30-foot plots. Five 10×30-foot plots were used in 1979 and 1980.

The medium textured Yalesville and Cheshire soils have a moderate moisture holding capacity but the storage potential on the Yalesville soil is limited by its shallow depth. The characteristics of the soil at all sites are given in Table 1.

Soil amendments

Initial evaluation of the Day-Waverly plots clearly indicated that the low moisture holding capacity of the very sandy soil would limit the growth of vegetables. Among the means available to overcome this problem are green manure crops dug into the garden soil. The resulting increases in soil organic matter and in soil moisture retention are modest, short-lived, and require repeated application (Downs et al., 1962). We were seeking a more permanent solution, so we tested several methods in 1976. On one 10×20-foot plot, 3 inches of well decomposed leaf-mold was rototilled to a depth of 6 inches. On a second plot, 6 inches of a finer textured topsoil was spread on the native sandy soil. In a third plot, four sheets of newspaper were buried 0.5 inch in the native soil to reduce evaporation. These were placed between the rows of plants after seeds had germinated and seedlings had recovered from the shock of transplanting. A fourth, untreated plot served as a control. All plots were fertilized as needed based on soil tests (Lunt et al., 1950); the leaf-mold and topsoiled plots received 4 lbs of 10-10-10 fertilizer; the paper-mulched and control plots received 6 lbs of 10-10-10 fertilizer. The topsoiled plot received 6 lbs of ground limestone. The other plots received none because of the high pH of the sandy fill. The leaf-mold plot needed an additional 3 lbs 10-10-10 fertilizer in mid-July. The other plots had medium to medium-high levels of N, P, and K in mid-July. Thus, no additional fertilizer was required.

In 1976, leaf-mold appeared to be a promising and economical amendment, but some nutrient deficiencies were noted. Thus, we turned our attention in 1977 to rates and timing of fertilization. The plots were modified as follows: Topsoil was removed from the topsoiled plot to expose the sandy soil. Most of the newspaper mulch had disintegrated, however, what remained was removed. These plots and the control plot then received 3 inches of leaf-mold and were rototilled to a depth of 6 inches. The leaf-mold plot remaining from 1976 received no additional leaf-mold. The plots received 6, 8, and 11 lbs fertilizer in 1, 2,

Table 1. Characteristics of sites and soils.

	Day-Waverly Gardens	Lockwood Farm	
Location	Downtown New Haven	Mt. Carmel	Mt. Carmel
Physiography	Glacial outwash terrace	Drumloidal hill	Drumloidal hill
Parent material	Sandy builder's fill	Loamy glacial till	Loamy glacial till
Depth to bedrock (inches)	> 120	12-14	> 48
Elevation above m.s.l. (feet)	40	200	200
Climate: (Havens & McGuire, 1961)			
Average last frost of spring	April 12	May 2	May 2
Average first frost of fall	October 26	October 7	October 7
Average frost-free days	197	158	158
Soil series	Unnamed	Yalesville taxadjunct	Cheshire
Texture	Loamy coarse sand	Loam/fine sandy loam	Loam/fine sandy loam
% sand	76	51	52
% silt	22	41	38
% clay	2	8	10
Volume coarse fragments (range)	18-40	5-15	5-15
pH	6.9	5.5	5.5
Plot size (feet)	(4) 10 × 20	(4) 10 × 30	(5) 10 × 30
Total square feet	800	1200	1500

and 3 applications, respectively. The dates and rate of application of 10-10-10 fertilizer are reported in Table 2.

In 1977 the 10×30-foot plots at Lockwood Farm were amended with 1, 2, and 3 inches of leaf-mold and rototilled to a depth of 6 inches. A fourth plot without leaf-mold served as a control. No additional applications of leaf-mold were made in 1978 when the plots were used to study improved methods of germination in leaf-mold amended soils.

In 1979 the five 10×30 plots were treated as follows. Two plots received 5 inches of raw leaves in the Fall of 1978. One plot was rototilled and hand forked to work in the raw leaves. The leaves remained on the second plot as a mulch during the winter and were incorporated into the soil in the Spring of 1979. Three inches of partially decomposed leaves (1 year old) and 1 inch leaf-mold (2 years old) were rototilled into the third and fourth plot. The fifth plot received no leaf material and served as a control.

In 1980, leaf applications were reversed. The plots that received leaf-mold and partially decomposed leaves in 1979 each were treated with 5 inches raw leaves rototilled and hand forked in the spring. Of the two plots that received raw leaves in 1979, one was treated with 1 inch leaf-mold, the other with 3 inch partially decomposed leaves rototilled in 1980.

All plots were fertilized in 1977-1980 with 10-10-10 fertilizer and lime according to soil tests. The amounts added are reported in Table 3. Soils were tested frequently to insure that plant nutrients were adequate during the growing season. Additional fertilizer was added to portions of the plots planted to fall crops. Second plantings of beans received ¾ lb 10-10-10 fertilizer per plot spread along the 10-foot row. The corn rows, used for a second planting of fall cabbage, cauliflower, and broccoli were amended with 1¼ lbs of 15-15-15 fertilizer and 1½ lbs of limestone in 1977-1980.

Temporary plastic mulching and temperature measurements

In 1978, one-half of each 1977 plot was covered lengthwise with 4 mil clear plastic following planting of paired rows of beets, carrots, radishes, yellow squash, butternut squash, and corn. One row of each crop was sown with known numbers of seeds treated with the fungicide, Captan; the other row was sown with untreated seed. The clear plastic, designed to increase soil temperature, was removed shortly after seed germination to prevent scorching of the emerging shoots. Counts of germinating seed were made for a two-week period. Late-morning temperatures of the soil at a 2.5 inch depth were taken at 2 to 3 day intervals beneath the plastic film and in the adjacent bare soil in all plots from planting to full germination.

Table 2. Rate and time of 10-10-10 fertilizer applications. Day-Waverly Gardens, 1977.

	Plot		
Date	3 Applications (1.8 X)	2 Applications (1.3 X)	1 Application (X)
	lbs		
May 4	6	6	6
June 3	2	2	..
July 11	3	..	..
Total	11	8	6

Table 3. Pounds of fertilizer and lime added to leaf-mold and raw leaf plots 1977-1980.

	3″ Leaf-mold	2″ Leaf-mold	1″ Leaf-mold	Control
1977				
Fertilizer 10-10-10	6	6	6	6
Limestone	9	12	15	21
1978				
Fertilizer 10-10-10	6	6	6	6
Limestone	5	5	5	5
	Raw leaves (2 plots)	Partially decomposed leaves	Leaf-mold	Control
1979				
Fertilizer 10-10-10	6	6	6	6
Limestone	12	12	12	12
1980				
Fertilizer 10-10-10	8	8	8	8
Limestone	15	15	15	15

Vegetables grown

The vegetables grown are common to Connecticut's backyard gardens. Yellow squash, butternut squash, snap beans, carrots, and beets were grown from seed; lettuce, tomatoes, cabbage, broccoli, peppers, and eggplant were grown from transplanted seedlings; onions were grown from sets. Some varieties were changed from 1976 to 1980.

Corn, which requires a large area, was not grown at the Day-Waverly plots. A plan showing the arrangement of vegetables and spacing between rows is found inside the cover. The spacing between rows was closer than recommended for Connecticut gardens (Conn. Ext. Serv., 1968) but the rows were arranged so that taller plants would not shade shorter ones.

Cultivation

All experimental plots were cultivated as needed to control weeds and to maintain a friable soil surface for maximum infiltration of water. Weeds within the rows were pulled by hand to eliminate competition for water and nutrients.

Irrigation and sampling for moisture

The experimental plots became the focus of attention in the Day-Waverly Gardens. They were watered amply by neighboring gardeners as they watered their own plots. For one week in mid-summer 1976, the plots were not watered to allow the soil to dry deeply. Soil samples were then taken to estimate the moisture content at the wilting point. Samples were also taken 24 hours after a heavy rainstorm in August to estimate the water content at field capacity in each plot. The difference between the two measurements indicates the amount of water available to growing plants.

The plots at Lockwood Farm received irrigation if plants became severely wilted. However, only two or three irrigations were necessary in mid-summer each year. Soil samples were taken following heavy rains and during droughty periods to estimate moisture holding capacity of the plots amended with varying amounts of leaf-mold.

Pest control

Insects were controlled in all plots as needed. Diazinon drench controlled cabbage maggots. Aphids and cabbage loopers were controlled with rotenone. Methoxychlor dust controlled squash vine borers and bean beetles with varied success. Corn borers were controlled with Sevin. Tomato hornworms were destroyed by hand.

Harvest

All vegetables were harvested when they reached marketable size. Weights of all vegetables were recorded as soon as they were picked. The value of the produce was determined by retail prices at the date of harvest.

RESULTS

Leaf-mold had a pronounced effect on the moisture holding capacity, the pH, and temperature of the soil. These factors influence germination of vegetable seeds and crop yields.

Improved available moisture holding capacity

The soil in the paper-mulched and control plots of the Day-Waverly Gardens was 95 and 83% sand, respectively. The texture of the former was a coarse sand; the latter, a loamy coarse sand. Table 4 shows less than 1 inch of water was retained at field capacity in the upper 6 inches of both plots. The amount available for plant growth was only 0.5 inch. Since many plants use as much as 0.2 inch of water per day, both plots could become deficient in 2 to 3 sunny days. The paper mulch plot was the sandiest of all plots and also contained the most stones. It appeared to have been part of an old gravelled driveway. Under these circumstances the water holding capacity was probably less than 0.5 inch, but the paper mulch improved it slightly. The greatest benefit of the paper mulch was its suppression of weeds. This plot required little attention other than watering.

Table 4. Physical properties of the garden plots.

Treatment	Organic Matter %	Volume Stones %	Inches of Water at Field Capacity	Inches of Water at Wilting Point	Inches of Water Available to Plants
			Day-Waverly Gardens		
Leaf-mold	16.1	18	1.9	0.6	1.3
Topsoil	4.0	10	1.2	0.5	0.7
Paper mulch	5.6	39	0.8	0.3	0.5
Control	5.2	28	0.9	0.4	0.5
			Lockwood Farm Gardens		
Leaf-mold 3"	9.6	....	2.0	0.9	1.1
Leaf-mold 2"	7.0	....	1.7	0.8	0.9
Leaf-mold 1"	6.7	....	1.6	0.8	0.8
Control	4.5	....	1.5	0.7	0.8

The plot covered with topsoil contained 72% sand and its texture was classified as a sandy loam. Its moisture holding capacity of 0.7 inch in the upper 6 inches of soil (a 3- to 4-day supply) was 25 to 35% greater than in the native soil.

Although the mineral portion of the leaf-mold plot was nearly 90% sand, the organic fraction was 4-fold greater than on the other plots. This organic matter held nearly 2 inches of water in the upper 6 inches; about a 7-day supply, 1.3 inches, was available to plants. All crops grown on the leaf-mold plot resisted wilting 2 to 3 days longer than the crops on the other plots. The added moisture supply also increased the resistance of tomato plants to blossom-end-rot. Droughty conditions on the other plots increased the incidence of this physiological damage, which is caused by an imbalance between the water needs of the plant and the supplying ability of the soil. During the 1977 growing season, however, tomato plants on all plots amended with leaf-mold suffered some damage from blossom-end-rot. Although addition of leaf-mold did not prevent damage, it reduced the damage.

The Yalesville and Cheshire fine sandy loams at Lockwood Farm have moderate moisture holding capacities. Table 4 shows that the Yalesville soil holds 1.5 inches of water at field capacity in 6 inches of topsoil and can supply plants with about 0.8 inch of water, a 4-day supply. Addition of 3 inches of leaf-mold doubles the organic content of the Yalesville soil to 9.6%. The amount of water held at field capacity increased 33% to 2 inches. The moisture available to plants increased 0.3 inch (a 1- or 2-day supply) in the plot amended with 3 inches of leaf-mold. At lower rates of leaf-mold application, increases in available moisture were negligible. Thus, the benefits of leaf-mold to increase moisture to growing plants are less dramatic on fine sandy loams and loams than on loamy sands and sands.

Soil temperature

Soils amended with leaf-mold are dark in color. Thus, one might expect their temperatures to be higher because of high absorption and low reflection of sunlight. The increase in moisture holding capacity of the soil and the slower conductivity for heat, however, offset any difference in absorption.

Temperatures were, in fact, cooler at 2.5 inches. At Lockwood Farm, late morning temperatures at a 2.5-inch depth on sunny days were about 3- to 4°F lower on the plot amended with 3 inches of leaf-mold than on the untreated plot. In the plots amended with 5 inches of raw leaves and 3 inches of partially decomposed leaves, soil temperatures at 2.5 inches were also suppressed 3- to 5°F. Addition of 1 or 2 inches of leaf-mold to the Yalesville soil produced no temperature differences compared to the control but 1-inch of leaf-mold in the Cheshire soil suppressed soil temperatures 4°F.

Clear plastic, half covering the plots in Yalesville soil during the period of seed germination in May 1978, raised soil temperatures 10- to 12°F on sunny days compared to the uncovered portion of the plots.

Germination of seeds

The use of leaf-mold and raw leaves as soil amendments caused problems in the germination of seeds planted in early- to mid-May. The increased moisture holding capacity of soil treated with these organic amendments causes them to warm more slowly and delays germination of seeds. The seeds surrounded by a microbiologically enriched soil have an increased potential to rot before germination. The following observations were made during a period of cool, wet weather in early May 1976. Deeply planted bean and squash seeds rotted in the leaf-mold plot and had to be replaced. Small, shallowly planted seeds germinated as expected on this plot. All seeds germinated on the other plots, which were drier.

At Lockwood Farm, seeds were planted on May 12, 1977. Small carrot, beet, and radish seeds germinated most rapidly on the control and 1-inch leaf-mold plots. Germination was delayed 3-5 days on the 2- and 3-inch leaf-mold plots; many seeds failed to germinate, leaving gaps in the row. Gaps were replanted on May 31. Germination of reseeded areas was prompt and complete except for beets on the 3-inch leaf-mold plot. On this plot, the final density of beets was only 75% of the density on other plots.

By May 26 only 45 to 68% of snap beans and 40 to 73% of summer squash had germinated on all plots. Germination was best on the 3-inch leaf-mold plot and worst on the control and 1-inch leaf-mold plots. This was contrary to our observations in 1976. Since the Lockwood Farm plots had a higher moisture holding capacity than the sandy Day-Waverly plot, it appears that they warm more slowly in early spring. Clearly, the seeds were planted too early for complete germination in the Yalesville soil. Germination of second plantings of snap beans and corn in late May and June was rapid and virtually complete.

In 1978 we sought methods to improve germination of seeds on the leaf-mold amended plots. The portions of rows covered with clear plastic increased the soil temperature and caused seeds to germinate about 2-3 days more rapidly; however, percentages of germinating seeds were not improved from those reported for 1977. In fact, germination of radish, beet, and yellow squash seeds planted shallowly beneath the plastic was reduced 15-45% compared to germination in uncovered soil. In the rows planted with Captan-treated seed, plastic covering also reduced germination of beets, yellow squash and radishes 5-20% below germination in uncovered soil. In uncovered portions of the rows, germination of Captan-treated bean seed improved 20%, corn germination improved 15%, and beet germination improved 70% compared to untreated seed. Yellow squash and radishes were unaffected by Captan treatment. Thus, treatment improved germination of some but not all seed species in soils amended with leaf-mold. The use of clear plastic was detrimental although germination was speeded.

Effect of leaf-mold on soil pH

Leaves that have been composted at temperatures of 140-160°F where thermophyllic organisms predominate produce a compost rich in soluble salts with a pH of about 7.0 (Sawhney, 1976). Leaf-mold added to Yalesville fine sandy loam increased soluble salt to 520 parts per million in the 3-inch leaf-mold plot. This concentration of salts is less than the amount added in normal fertilization and presents no problems when added to field soils. The pH of the Yalesville soil (5.5) increased to 6.1 when 3 inches of leaf-mold were rototilled to a depth of 6 inches. Only 30 lbs/1000 ft^2 ground limestone were needed on the 3-inch leaf-mold plot whereas 70 lbs/1000 ft^2 were needed on the control plot to raise the pH to the optimum level (6.5).

Leaf-mold applied to mortar-laden sandy fill in the Day-Waverly plots produced no changes in pH because both materials were about neutral (7.0). Raw leaves added to Cheshire fine sandy loam (5.6) increased pH to about 6.0, but as the leaves degraded in the soil in late summer, the pH declined to 5.6 despite addition of limestone. By this time, however, the control had also declined to 5.4. Optimum pH levels (6.5) were not attained in any plots in 1979.

Yields of vegetables

The yields of vegetables grown at the Day-Waverly plots in 1976 are reported in Table 5. Leaf-mold consistently increased yields. The harvest of peppers and onions was 240-250% of the yield on the control plot. Yields of lettuce, carrots, tomatoes, and eggplant were about 120-145% of the yields on the untreated plot. The yields of snap beans, yellow and butternut squash, and beets were less than the yields on the control

Table 5. Vegetable Yields*—Day-Waverly Gardens—1976. Improvement of moisture holding capacity.

	Plot						
	Leaf-mold		Topsoil		Paper mulch		Control
	lbs	% of Control	lbs	% of Control	lbs	% of Control	lbs
Beets (wo/tops)	4.5	72	4.2	68	3.7	60	6.2
Butternut squash	3.8	58	1.9	29	8.0	123	6.5
Carrots (wo/tops)	7.2	122	5.7	97	4.1	69	5.9
Eggplant	13.8	134	9.4	91	5.8	56	10.3
Lettuce	6.1	130	3.9	83	1.6	34	4.7
Onions	1.5	250	1.2	200	0.4	67	0.6
Peppers	5.0	238	3.0	143	2.8	133	2.1
Snap beans (2 rows)	3.0	81	5.4	146	3.2	86	3.7
Tomatoes (2 rows)	40.3	143	27.2	96	28.5	101	28.2
Yellow squash	5.4	47	28.3	248	6.9	60	11.4

* Yields are for 10-foot rows: snap beans and tomato yields should be divided by 2.

plot. These lower yields were mostly due to poor germination in the wetter, cooler soil of early spring as previously described.

The yields of most vegetables on the topsoil plot were intermediate between yields on the leaf-mold and control plots. Only the yields of snap beans and yellow squash exceeded yields on the leaf-mold plot. The yields of vegetables on the paper mulch plot were generally a fraction of the yields on the control plot. Only the yields of peppers and butternut squash exceeded the yields of the control plot. Of all plots, this plot had the coarsest soil texture and the greatest volume of stones. While the paper mulch undoubtedly helped conserve water, the amount of water still fell short of the requirements for satisfactory growth of vegetables.

The yields of vegetables grown in the fertilizer experiments in the Day-Waverly plots in 1977 are reported in Table 6. I report the data only from the three plots receiving 3 inches of fresh leaf-mold in 1977. Although vegetables were grown on the original leaf-mold plot of 1976, it was used as a buffer because it was located next to a walkway. We have averaged the yields in the plots receiving two and three applications of fertilizer and compared them with the control plot receiving one application. Late maturing beets, carrots and peppers benefited from supplemental fertilization. Broccoli benefited from supplemental fertilization because shoot growth was picked throughout the growing season. Cucumbers planted as a second crop following lettuce responded best to supplemental fertilization. The remaining crops, mostly early maturing ones, did not benefit from additional applications of fertilizer. Snap beans, yellow squash and lettuce were nearing maturity or harvested before the third application. Benefits from the third application in July were generally negligible.

Table 6. Vegetable Yields*—Day Waverly Gardens—1977. Fertilizer experiments.

	Average of 2 and 3 Applications (1.3 and 1.8X)		Control 1 Application (X)
	lbs	% of Control	lbs
Beets (w/tops)	5.6	143	3.9
Broccoli	2.8	127	2.2
Carrots (w/tops)	5.1	121	4.2
Cucumbers	6.9	255	2.7
Eggplant	14.7	102	14.4
Lettuce	9.8	96	10.2
Onions	1.1	58	1.9
Peppers	6.8	121	5.6
Snap beans (2 rows)	5.4	86	6.3
Tomatoes (2 rows)	21.8	67†	32.3
Yellow squash	12.1	107	11.3

* Yields are for 10-foot rows: snap beans and tomato yields should be divided by 2.

† Severe damage by blossom-end-rot.

The total yields of all crops at the Day-Waverly plots were about 10% less in 1977 than in 1976. Most of this loss can be attributed to loss of yellow squash, which was severely injured by an early invasion of squash vine borers. Tomato yields were also down 25% due to blossom-end-rot. Although the increased moisture holding capacity of leaf-mold failed to protect fully our plots against moisture stress, we observed far greater losses on plots without leaf-mold.

Compared to 1976, decreased yields of yellow squash and tomatoes were offset by increased yields of snap beans (45%) and lettuce (150%). Lettuce yields were superb because transplanted seedlings were used instead of seeds. The plants matured more rapidly and took advantage of cool, moist weather in early spring. The 1977 lettuce crop matured in mid- to late-June while the 1976 crop, which was started from seed, had smaller heads when summer dryness set in.

The yields of vegetables grown at Lockwood Farm are reported in Table 7. The highest yields of yellow squash, lettuce, beets, carrots, tomatoes, eggplant, and swiss chard occurred on the 1-inch leaf-mold plot. Total yield of all vegetables was 11% greater on the 1-inch leaf-mold plot than on the control plot. Duncan's Multiple Range Test showed that these increased

Table 7. Vegetable Yields*—Lockwood Farm—1977. Leaf-mold application rates.

	Leaf-mold plot						Control
	3-inches		2-inches		1-inch		
	lbs	% of Control	lbs	% of Control	lbs	% of Control	lbs
Beets (w/tops)	7.8	58	13.5	101	16.0	119	13.4
Broccoli	12.3	126	11.4	116	9.3	95	9.8
Butternut squash	21.9	296	10.4	140	13.1	177	7.4
Cabbage (2 crops)	20.0	116	14.4	84	15.7	91	17.2
Carrots (w/tops)	14.0	93	13.4	89	21.6	143	15.1
Eggplant	10.8	127	9.0	106	12.1	142	8.5
Lettuce	12.7	95	14.8	110	15.0	112	13.4
Onions	4.0	89	3.7	82	4.8	107	4.5
Peppers	1.2	32	1.9	50	2.3	60	3.8
Snap beans	15.1	85	13.4	75	15.2	85	17.8
Swiss Chard	7.9	87	11.8	130	12.3	135	9.1
Tomatoes (2 rows)	71.9	94	75.4	99	82.9	108	76.5
Yellow squash	117.0	110	107.1	101	117.1	110	106.1

* Yields are for 10-foot rows: tomato yields should be divided by 2; cabbage and broccoli were interplanted.

yields were statistically significant. Yields of broccoli, cabbage, and butternut squash were greatest on the 3-inch leaf-mold plot. Although no vegetables had the highest yields where 2 inches of leaf-mold were added, yields of lettuce, eggplant, broccoli, swiss chard, and butternut squash were higher than on the control plot. The total yield from 2 inches of leaf-mold matched the total yield on the control plot. Yields of peppers on all leaf-mold amended plots were low; the prolific yellow squash crowded the peppers and successfully competed for water, nutrients and light.

It appears that 1 inch of leaf-mold helped produce consistently high yields for most vegetables. Yalesville soil crusts following rains, which reduces infiltration. Addition of leaf-mold undoubtedly reduces this tendency to crust.

The yields of vegetables grown in plots amended with raw leaves, partially decomposed leaves, and leaf-mold are reported in Table 8. The yields of lettuce and cauliflower were substantially increased by all organic amendments, but yields of onions and radishes were only improved with partially decomposed leaves and leaf-mold. Only the yields of cabbage were improved with partially decomposed leaves and only broccoli yields were improved with leaf-mold. Most

Table 8. Vegetable Yields*—Lockwood Farm—1979. Application of raw and partially decomposed leaves.

	5-inches Raw leaves†		3-inches Partially decomposed leaves		1-inch Leaf-mold		Control
	lbs	% of Control	lbs	% of Control	lbs	% of Control	lbs
Beets (w/tops)	7.6	55	13.1	95	12.4	90	13.8
Broccoli	10.6	105	9.1	90	11.7	116	10.1
Cabbage	4.1	89	7.8	170	4.6	100	4.6
Carrots (2 rows-wo/tops)	23.4	81	27.1	94	29.6	103	28.8
Cauliflower	10.3	161	14.8	231	11.8	184	6.4
Corn‡ (3 rows)	8.0	75	9.1	86	9.3	88	10.6
Lettuce	11.3	124	11.1	122	12.8	141	9.1
Onions	2.6	68	4.6	121	5.1	134	3.8
Peas (2 rows)	7.2	77	8.4	90	7.8	84	9.3
Peppers	4.6	52	4.9	55	5.8	65	8.9
Radishes (3 crops)	6.1	98	9.8	158	7.8	126	6.2
Rutabaga	23.9	77	34.8	112	25.4	82	31.0
Snap beans (2 rows-2 crops)	20.4	66	23.6	77	32.1	104	30.8
Tomatoes	39.4	68	53.0	91	53.8	92	58.3
Yellow squash	80.1	101	85.6	108	87.9	111	79.4
TOTAL WT.	259.6	83	316.8	102	317.9	102	311.1

* Yields are for 10-foot rows; snap beans, peas, and tomato yields should be divided by 2; corn yields by 3; cabbage and broccoli were interplanted.

† Average of 2 plots (plowed fall; mulched fall and plowed spring).

‡ ½ total wt. of ear.

vegetable yields were reduced by amendment with raw leaves either plowed under in the fall or mulched over the winter and plowed under in the spring. Under these conditions, reduced total yield was fully 17% compared to the control. These suppressed yields are consistent with suppressed yields noted in plots mulched with raw leaves and in greenhouse studies where tomato and broccoli plants were watered with leachate from composting leaves (unpublished data). During initial decomposition of leaves, substances are released that apparently inhibit growth of vegetable plants and reduce their subsequent yields.

By mid-June snap bean plants were 20% shorter and tomato and pepper plants were 10% shorter than controls in plots amended by raw leaves, while these plants were 10-15% taller in plots amended with leaf-mold. Height differences disappeared by early August as the plants matured. Yields were suppressed in the plots amended with raw leaves although soil tests showed all plant nutrients were in adequate supply throughout the growing season.

The total yields of all vegetables harvested in plots amended with partially decomposed leaves and leaf-mold differed little from the total yields of the control plot. This is inconsistent with the results obtained in 1977 and 1978 where 1-inch leaf-mold improved yields an average of 15% compared to the control. We note that the 1979 experiments were in an area formerly occupied by turf untended in 1978, and the turf plowed under in the fall of 1978 supplied much organic matter. The organic content of the control plot (6.8%) was 50% higher than the organic content reported for the earlier control plot in Table 4 (4.5%). Thus, it is not surprising that additional organic amendments from leaves in various stages of decomposition had little effect on crop yields except where plant growth was inhibited by substances released from newly decaying leaves.

In 1980, the treatments were reversed from 1979 to test if suppression of yields by raw leaves persists a second year or if its expression is only short-lived. The relative yields of many vegetables among treatments in 1980 were consistent with yields reported in 1979 (Table 8). The yields of root crops especially beets, carrots, and radishes in the raw leaf plots were again the lowest of all treatments. Radish yields were suppressed 30%, beets 16%, and carrots 5% compared to the control. Yields of tomatoes and cabbage were suppressed 8%, and 29%, respectively on the raw leaf plots in 1980 compared to the control and are also consistent with 1979 yields. The suppression of the tomato yields on the raw leaf plot, however, was not as great as the 32% reported in 1979. Rutabaga was less affected by raw leaves than other root crops because it was planted as a second crop for fall harvest. Further, vegetables suppressed in 1979 by application of raw leaves, were not suppressed by leaf-mold or partially decomposed leaves in 1980. This suggests that the deleterious effect of raw leaves on most crops comes at the early stages of decomposition of the leaves and does not carry over to a second year unless raw leaves are applied again.

The greatest yields of many individual vegetables in 1980 were found on the plots treated with leaf-mold and partially decomposed leaves and are consistent with yields of 1979. Beets, onions, rutabagas and cabbages thrive on the partially decomposed leaf plots, while carrots, radishes, tomatoes, and squash have high yields on leaf-mold.

The total yields of all vegetables harvested on each plot in 1980 are compared with total yields of 1979 in Table 9. The total yields of all leaf-amended plots in 1980 were significantly greater than in 1979. This was due largely to a substantial increase in yields of tomatoes, yellow squash, cabbages and beets on all leaf amended plots. Increased yields, especially of tomatoes and yellow squash, are attributed to better control of tomato aphids and squash vine borers. Total yield of vegetables on the control plot in 1980 was slightly reduced from 1979, mostly at the expense of lettuce, snap beans, carrots, broccoli, and rutabagas. In 1980, total yields on all leaf-amended plots were significantly greater than the control. Although yields of some vegetables on the raw leaf plot were suppressed compared to the control, the overall yield of this plot was greater than the control. Total yields on the plot amended with partially decomposed leaves was fully 25% greater than the control: the total yields on the leaf-mold plot were 19% greater.

The decline in productivity on the control plot was probably due to changes in the physical condition of the plot. The soil was more compact and less friable in 1980 than in 1979 as the fresh organic matter supplied by the original sod cover decomposed. The growth of carrots and rutabagas was especially inhibited by the denser soil. Measurements of organic matter showed that its content declined from 6.8% in April 1979 to 6.0% in November 1980, a 13% decrease. Thus,

Table 9. Total yields of all vegetables harvested on each plot 1979-1980.

	5-inches Raw leaves*		3-inches Partially decomposed leaves		1-inch Leaf-mold		Control
	lbs	% of Control	lbs	% of Control	lbs	% of Control	lbs
1979	260	83	317	102	318	102	311
1980	342	114	376	125	356	119	300

* Average of 2 plots

the benefits accrued by supplying leaf materials to the garden soil regardless of the stage of decomposition outweighed the suppressing effects of raw leaves on some crops. The reduced yields of vegetables on the control plot illustrates the need for organic amendments to maintain unrestricted growth of plant root systems.

Yearly decomposition rates and maintenance of leaf-mold

Leaf-mold worked into the soil continues to degrade due to the action of bacteria and fungi. Because the amount of leaf-mold in the soil decreases during the growing season, it is important to know how much is left for next year's crop. At the Day-Waverly plots 3 inches of leaf-mold added to the sandy builders' fill in 1976 increased the organic matter from 5 to 16%. In 1977 the organic content of the leaf-mold plot decreased to 11%.

It appears that slightly more than 1 inch of leaf-mold per year is needed to maintain an organic content of about 15%.

Addition of 3 inches of leaf-mold to the finer textured Yalesville soil increased its organic content from 5 to 10%. Following two growing seasons, the organic content had decreased to 8%. Annual addition of three-fifths of an inch leaf-mold would maintain the organic level at 10%. However, approximately one-third inch could be added each year or 1 inch every 3 years because the greatest crop yields were realized at an organic content of 7%.

DISCUSSION

Planning for maximum yield

Successful gardening does not come easy. Planning, planting, and perspiration are required. The garden plots at Lockwood Farm were planned for maximum yields. Spacing between rows was narrowed from recommended spacing (Conn. Ext. Serv. 1968). The yellow squash rows were narrowed from 36 to 24 inches. Bean rows were reduced from 24 to 12 inches. Beets, carrots, onions, and lettuce rows were set 12 inches apart, the narrower spacing of the recommended range. The narrow spacing allowed a greater variety of vegetables to be grown in the 30×40-foot garden. One useful space saver was planting butternut squash within rows of tomatoes. Since tomato plants were staked upright, there was sufficient room for the squash vines to run. The greatest competition for space was by yellow squash vines. Although their yields were outstanding (Table 7), the pepper plants in the adjacent row were stunted and their yield reduced. In the south-facing garden, planting tall crops behind shorter ones prevented shading in the afternoon and provided ample sunlight. Only cucumbers grown on a chickenwire fence at the rear of the plots were shaded by corn. Once the corn was harvested and the plants removed, the cucumbers grew rapidly. Crowding of some vegetables led to difficulties in hoeing weeds and harvesting. Despite crowding, yields were probably greater than average for Connecticut gardens.

Planning for second crops is also worthwhile for maximum yield as well as staggered planting of crops to prolong harvest of a single crop. There are two forms of staggered planting. Whole rows of beans and corn were planted 2 weeks apart in May. Where germination of seed is poor in leaf-mold amended soil, replanting the gaps in the row produces a partial second crop. This is especially useful for beans, radishes, carrots, and beets. Second plantings of early vegetables usually suffer diminished yields as plants mature during periods of moisture stress in August.

Our corn rows were replaced in early August by late varieties of cabbage, broccoli, and cauliflower. Since cauliflower failed to mature following corn, we used it as a second crop following harvest of peas in early July. Broccoli can be picked to early December. Root crops can be mulched with hay, grass, or leaves to retard frost and picked during winter months. Although it is generally ill-advised to follow one root crop with another because of increased potential of maggot injury, a rutabaga crop following radishes was highly successful.

Since optimum moisture produces maximum yields, supplemental irrigation is necessary during the summer months. Droughty soils can be made to hold more water with leaf-mold. Fertility needs to be checked periodically so that nutrient deficiencies do not occur. Delayed ripening of tomatoes may occur if nitrogen levels are too high in mid-summer. Competing weeds are removed by cutting with a hoe or, within rows, by pulling. Most plant pests can be controlled as they appear.

Economic value of a garden plot

To estimate the economic value of vegetables, we recorded prices at a local market and determined the value of vegetables on the day of harvest.

In 1976 the Day-Waverly plots produced 450 lbs of vegetables per 1000 ft^2, with an economic value of \$213. The greatest return was from tomatoes and yellow squash, which accounted for nearly half of the value. Eggplant also produced significant yields. Maishe Dickman, garden coordinator of the Greater New Haven Arts Council, also maintained a record of his yields in 1976. The economic value of his crops per 1000 ft^2 was \$218. Although he did not use leaf-mold, his plots were watered considerably more than the experimental plots. In 1977, the total yield at the Day-Waverly plots was 410 lbs, a decrease of about 10% from 1976. The value of the 1977 crops was \$193 per 1000 ft^2. Most of the yield decrease was due to blossom-end-rot which destroyed 25% of the tomato crop.

Agricultural Statistics (1976) indicates that the annual per capita consumption of fresh vegetables is

143.2 lbs. Thus, we concluded that with proper care, 1000 ft^2 in the Day-Waverly plots could provide fresh vegetables for about 3 persons.

The plots at the Lockwood Farm yielded at the rate of 1120, 1000, 1027, and 1215 lbs of vegetables per 1000 ft^2 in 1977-1980 with an economic value of $445, $456, $521, and $600, a clear indication of increasing prices and value despite declining yields from 1977 to 1979. In 1980, the increased yield fully accounts for the increased value. These yields represent a 2.5-fold increase in both weight of vegetables and economic value over the Day-Waverly plots. The greatest return was from the tomato and yellow squash crops, which accounted for 40-50% of the cash value each year. Three crops of radishes, two crops of snap beans, carrots, broccoli, corn, cauliflower, and rutabaga exceeded a value of $35 for each 50-foot row. The Lockwood Farm plots produced enough vegetables to support 7-8 persons, a 2.5-fold increase over the Day-Waverly plots.

CONCLUSIONS

From our experiments using leaf-mold as an organic amendment to garden soils we concluded the following:

- Leaf-mold added to sandy soil significantly improved the moisture holding capacity and added a 3- to 4-day moisture supply for growing plants.
- Leaf-mold added cohesiveness to a very sandy soil, improved the structure of a fine textured soil, reduced surface compaction following rains, and allowed greater infiltration.
- Leaf-mold produced by high temperature decomposition had a neutral pH and reduced the lime requirement for an acid soil.
- Three inches of leaf-mold added to soils of sand and loamy sand texture significantly improved vegetable yields. One inch of leaf-mold will suffice for fine sandy loam or loam textures.
- Repeated applications of 1 inch of leaf-mold each year maintained suitable amounts of organic matter in very sandy soils. One inch of leaf-mold can be added to fine textured soils every 3 years to improve soil structure and lessen compaction.
- Although leaf-mold has little fertilizer value, nutrient deficiencies often occur as leaf-degrading organisms compete with crops for nutrients. About 25% more fertilizer was beneficial when added late in June after the first flush of growth.
- Additions of leaf-mold may cause poor germination of seed in early spring. Warming the soil with clear plastic following seeding hastened germination 2-3 days but offered little protection against decay. Treating seed with the fungicide Captan improved germination of some seed crops, especially beets, snap beans and corn.
- Raw leaves as an organic amendment reduced yields of many vegetables, especially early root crops, up to 45% compared to the controls. Addition of partially decomposed leaves (1 year old) and leaf-mold (2 years old) improved yields of most vegetables, some significantly.
- With optimum fertilization and water, vegetables grown on a very sandy soil amended with leaf-mold can feed about 3 persons per 1000 ft^2. On a finer-textured soil, vegetable yields can feed 7.5 persons, a 2.5-fold increase.

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